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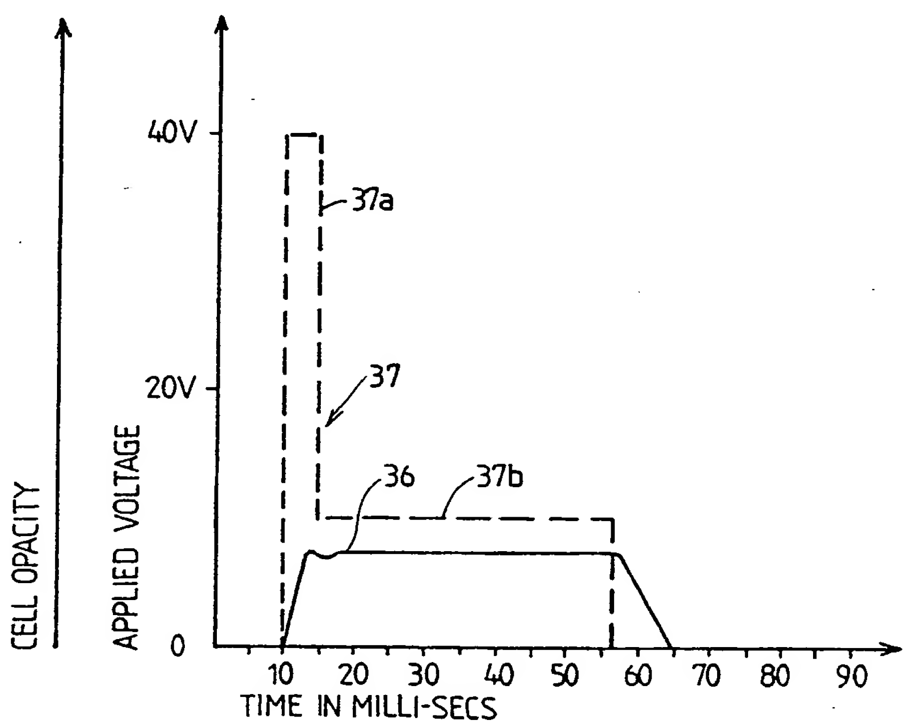
(54) Title: METHOD AND APPARATUS FOR CONTROLLING A LIQUID CRYSTAL DEVICE



(57) Abstract

A method for changing the state of a liquid crystal display device (10) to vary the opacity thereof wherein a short high voltage pulse (37a) considerably in excess of the critical voltage of the display device is applied thereto, the pulse being of short duration whereby to minimise the likelihood of damage to the device.

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METHOD AND APPARATUS FOR CONTROLLING A LIQUID CRYSTAL DEVICE

This invention relates to the activation of liquid crystal devices by the application of electric potential thereto to alter the state of some or all of the liquid crystal material thereof.

Nematic liquid crystal display devices are well known. These devices generally include transparent plates between which is positioned a thin layer of a nematic liquid crystal material. Light polarisers are positioned one to either side of the plates. Electrodes in the form of transparent conductive coatings, usually arranged in a desired pattern forming configuration, applied to the inner surfaces of the plates are provided and, when an electric potential greater than a critical voltage is applied across the electrodes, the liquid crystal material directly interposed between the electrodes is affected in such a way as to cause a change in the optical density of that part of the device coinciding with the electrodes. In particular, the liquid crystal material and light polarisers may be arranged so that before application of electric potential to the device light can freely pass through the device, but that on application of electric potential to the electrodes the optical density of the device coinciding therewith is greatly increased.

Devices such as above described suffer a disadvantage in that, in some applications, it is desired that the optical density should be changed rapidly from one state of optical density to another whereas,

generally speaking, there is a significant delay time between application of electric potential to effect change of state of the liquid crystal material and the actual occurrence of such change of state. This has somewhat tended to limit the use of liquid crystal devices in certain application to which they are otherwise well suited.

The field of application of the present invention and its nature may be better appreciated in the light of the prior art publications presently known to the applicant, namely:

U.S. Patent 4,071,912. This discloses a welder's mask in which the lens includes a liquid crystal layer the state of which is changed to opacify the lens by means of an UV-sensitive photocell responsive to exposure to a welding flame or arc.

U.S. Patent 4,241,286. This also relates to welder's masks but in which the opacifying is dependant on the welder blowing on, or making a sound to affect, a transducer within the mask.

U.K. Patent 2,029,343. This discloses modification of the reflectivity of a mirror by alteration of the on/off duty cycle of a high frequency controlling voltage of a liquid crystal device associated with the mirror.

U.K. Patent 1,430,183. This relates to similar subject matter as U.S. 4,071,912 but the photo-cell is within the mask so that it receives radiation

that has penetrated the lens rather than fallen directly on the cell.

U.K. Patent 2,083,649. This discloses a spectacles lens incorporating a liquid crystal device of which the opacity depends on the duty cycle of a high frequency energising potential.

German Patent 2,442,98. The opacity of a lens is controlled by feed back from a photo-sensor controlling variation of the voltage applied to a liquid crystal component of the lens to maintain a constant transmissability.

The present invention is applicable in all of the applications instanced in the abovementioned prior art and is also particularly, but not exclusively concerned with affecting a high speed change of state required in respect of welder's helmets or masks.

The response time, that is to say the time taken to achieve the change in state after application of an electric potential, can be significantly decreased by application of electric potentials which are significantly higher than the critical voltage. However, this expedient has a substantial disadvantage that the device may be damaged whilst, in any event, the useful life of the device is certainly lessened.

Generally speaking, the present invention contemplates the application a high electric potential

to the liquid crystal device, but only for a short period, when effecting change of state of the device by application of electric potential. It has been found that application of a short high voltage pulse of the order of, say, five milliseconds duration will effect very rapid change of state as compared with conventional methods, without causing significant lessening of life of the device.

In accordance with one aspect of the invention, then, there is provided a method of altering the state of a liquid crystal device, to vary the optical density of the device, comprising applying to the device a short pulse of high electric potential. The pulse may be followed by a maintained lower level of potential sufficient to maintain the change of state.

The invention also provides means for applying electric potential to a liquid crystal device for altering the state of the device, to vary the optical density of the device, arranged whereby on said applying of electric potential, the electric potential applied is generated as a relatively high magnitude pulse of short duration. The electric potential applied may be changed to a lower level after occurrence of said pulse. The pulse may be of magnitude 2 to 5 times the critical voltage for the device and the subsequent potential applied may be of magnitude substantially the same as but higher

than the critical voltage. The means for applying electric potential may comprise two voltage generators, one operable to apply a steady state voltage sufficient to maintain the liquid crystal display device in its

changed state and a higher voltage generator operable to supply the aforementioned pulse, together with means operable on application of potential to the device to effect supply of potential from the higher voltage generator for the duration of said pulse and to then effect supply of potential from said one generator. The last mentioned means may include timing means effective to effect turning off of potential supply from the higher voltage generator to terminate said pulse.

The said pulse and any electrical potential applied to maintain the change of state of the device may be direct current voltages, possibly of pulsating form, or may be alternating current voltages. For example, the pulse may be generated as a series of relatively high frequency signals such as 20KHz, whilst the subsequent maintenance electrical potential may be generated as an alternating voltage of relatively low frequency, such as 50 Hz.

The invention is further described by way of example only with reference to the accompanying drawings, in which:

Figure 1 is a cross sectional diagram of a conventional liquid crystal display device;

Figures 2 to 4 are graphs explaining the operation of the invention; and

Figure 5 is a circuit diagram of a representative supply device constructed in accordance with the invention.

In Figure 1, a liquid crystal display device 10 is shown as comprising two glass plates 12, 14 arranged in closely spaced parallel relationship and sealed around the edges by a seal 16 therebetween so as to maintain the inner surfaces of the plates spaced apart a small distance. The cavity within the device between the glass plates 12, 14 and seal 16 is filled with a nematic liquid crystalline material 20. Crossed polarisers 22, 24 are provided against the outer faces of the glass plates 12, 14 whilst the inner surfaces of the glass plates in contact with the material 20 are coated with a suitable transparent conductive material. In a fashion known _per se_ and described, for example, in United States Patent 3,731,986, application of electric potential above a critical value V_c to the layers 26, 28 causes the material 20 to change state from a state where light transmission through the device 10 is possible to a state where light transmission is substantially blocked.

It is customary to apply a voltage to the material 20 as an alternating current voltage in which case the RMS voltage needs to be in excess of the critical voltage V_c in order to effect change of state. It is possible, however, to use DC voltages. In Figure 2, graph 33 represents an applied alternating voltage of about 10 volts RMS applied at an arbitrary time "t" = 50 milliseconds as maintained for an arbitrary time period ending at t = 280 milliseconds. This voltage corresponds to an RMS voltage close to but somewhat above the

critical voltage V_c, for customarily used liquid crystal materials. The effect of application of this voltage on transmissivity of the device is indicated by graph 30. It will be seen that the optical density rises only relatively slowly on application of voltage and does not reach the maximum density until time t = 100 milliseconds. That is to say, there is an effective rise time of about 75 milliseconds before maximum density is reached. On turn off of applied voltage, there is also some time delay between such turn off and reversion of the device to its off state. As shown, this may typically be of the order of 40 milliseconds.

In Figure 3, the effect of increasing the applied voltage is demonstrated. Here, the applied voltage as representated by graph 35 is applied for the same time period as in Figure 2 but is of a higher magnitude, namely 15 volts, thus being considerably higher than the critical voltage V_c. The variation in optical transmissivity of the device 10 under application of this voltage is represented by graph 32 in Figure 2. The rise time for the device 10 to assume its most optically dense state from the rest state after application of this increased voltage is considerably lessened, being of the order of 30 milliseconds. However, it has been found that continued application of voltages of this order will rapidly cause deterioration of the device and damage it. Furthermore, the turn off time for the device to assume its off state after interruption of voltage supply

thereacross is considerably increased, being of the order of 70 milliseconds.

Figure 4 illustrates a cycle of operation of device 10, in accordance with this invention. Here, a voltage represented by graph 37 is applied. Over the bulk of the time period, represented by part 37b of graph 37, the voltage is maintained at the same level as in Figure 2, being sufficient to maintain turn on but not being so high as to be likely to cause damage to the device 10. However at initiation of turn on, the applied voltage is generated as a high magnitude pulse shown at 37a in Figure 4. The magnitude of the applied voltage represented by this pulse would be sufficient to cause damage to the device 10 were it applied for any significant length of time. However it has been found that by application of the high voltage for such a short duration, the life time of the device 10 is substantially unaffected. Furthermore, this high peak voltage has the effect of considerably reducing the turn on time, such as to the order of 2 milliseconds as shown by the transmissivity curve 36, whilst leaving the turn off time substantially the same as in the example of Figure 2.

Figure 5 shows an embodiment of a supply device 50 for providing the voltage waveform represented by graph 37 in Figure 4. In this instance, the voltage applied is an alternating voltage consisting a high frequency voltage of high potential to form the pulse 37a together with a lower frequency voltage component to form the

subsequent maintenance voltage as represented at 37b in Figure 4. The supply device 50 is operated from a twelve volt direct current supply (not shown). The supply device 50 includes a first oscillator 52 comprised of a Schmit inverter device 60 which has one input connected to a supply line 54 and its other input coupled to ground via a capacitor 113 and to its output terminal via a resistor 58. Line 54 is connected via a switch 56 coupled to the aforementioned twelve volt supply. Output from oscillator 52 is connected, on the one hand, to one of the conductive layers (26) of the device 10 and on the other hand to the two inputs of a second Schmit inverter device 61, the output terminal of which is connected via a diode 62 to the other conductive layer 28 of the device 10. A second oscillator 64 is formed from a Schmit inverter device 66 having both inputs connected together and coupled to ground via a capacitor 68. The inputs of device 66 are also connected to the output terminal of that inverter via a resistor 70. Output from oscillator 64 is taken via a capacitor 74 to a conventional voltage multiplier 80 comprised of three series connected capacitors 82, 84, 86 with capacitor 82 being bridged by two series connected diodes 88, 90 and capacitor 86 being bridged by two series connected diodes 92, 94. Diode 88 has a capacitor 96 connected in parallel thereacross whilst a further capacitor 98 is connected between the junction of diode 88 with diode 90 and the junction of diode 92 with diode 94. Output from the

voltage multiplier appears across a capacitor 100 connected between earth and the junction of diode 94 with capacitor 86. Supply from line 55 is provided to the voltage multiplier via a diode 106.

Oscillator 52 is a relatively low frequency oscillator of, for example 50Hz and is arranged to provide an alternating current supply voltage, via Schmit inverter device 60 and diode 62, of RMS voltage close to but somewhat above the critical voltage V_c for the device 10. The output from voltage multiplier 80 comprises a relatively high voltage alternating potential of, say, 40 volts and this output is connected via a line 102, a transistor 110 and a diode 112 to the device 10, particularly to the layer 28 thereof. Line 102 connects to the emitter of transistor 110 whilst diode 112 connects to the collector thereof. The base of the transistor 110 is connected via a capacitor 115 to the output of an inverter 122 having its input connected to line 55.

On initiation of operation of the supply device 50 by turning on of switch 56, supply is applied to effect operation of oscillators 52 and 64. At this time, the output of inverter 122 is immediately brought to a ground state pursuant to application of supply voltage to the inputs thereof, whereby the base of transistor 110 is connected to earth via capacitor 115. At the same time, the multiplied output voltage from oscillator 64 is applied to the emitter of the transistor from line 102.

The initial voltage conditions on the transistor 110 are effective to permit the oscillatory voltage on line 102 to pass through the transistor through diode 112 whereby the high voltage high frequency signal from oscillator 64 and multiplier 80 is applied across the device 10. However, during this operation, capacitor 115 charges and after a time period determined, _inter alia_ by the value of the capacitor 115 eventually reaches a state at which the terminal conditions of the transistor 110 are such as to turn the transistor off. Then, supply from the oscillator 64 to the device 10 is interrupted by breaking of circuit connection to diode 112. Thereafter, supply is provided to the device 10 from the oscillator 52 via inverter 60 and diode 62.

Thus, each time switch 56 is actuated to effect a new cycle of turn on of the device 10 the oscillator 64 operates to apply voltage to the device 10 for a time period determined by the value of the capacitor 115. As mentioned, this time period may be selected to be of the order of 5 milliseconds.

Generally speaking, in practising the invention, oscillator 52 may be arranged to provide alternating current voltages of frequency between 25 and 100Hz, in accordance with conventional practice as determined principally by the particular liquid crystal material used. The voltage generated by oscillator 52 may be of the order of 3 to 15 volts RMS depending on the liquid crystal material. The high voltage pulse provided by

oscillator 64 and multiplier 80 may be of voltage between 20 and 60 volts, applied for a time duration between 1 and 10 milliseconds. The frequency of operation of oscillator 64 is not critical, but frequencies of the order of 20 Khz, such as between 5 and 40 Khz, have been found satisfactory. it is prefereed that the frequency be higher than that of oscillator 52. The frequency of the oscillator 52 may, conveniently, be in the range 25 to 120 Khz.

The described arrangement has been advanced merely by way of explanation and many modifications may be made thereto without departing from the spirit and scope of the invention as defined in the appended claims.

CLAIMS:

1. A method of altering the state of a liquid crystal device, to vary the optical density of the device, comprising applying to the device a short pulse of high electric potential.

2. A method as claimed in claim 1 wherein said pulse has a peak potential of 2 to 5 times the critical voltage of the device.

3. A method as claimed in claim 2 wherein said pulse is formed from a high frequency alternating current signal.

4. A method as claimed in claim 3 wherein said pulse is provided as a DC voltage.

5. A method as claimed in claim 1 or claim 2 wherein said pulse is formed as a pulsating DC voltage.

6. A method as claimed in claim 1 or claim 2 wherein said pulse is an alternating current signal.

7. A method as claimed in claim 6 wherein said alternating current signal has a frequency in the range 5 to 40 Khz.

8. A method as claimed in claim 7 wherein said frequency is substantially 20 Khz.

9. A method as claimed in claim 3 or claim 4 wherein the peak potential of said pulse is in the range 20 to 60 volts.

10. A method as claimed in claim 7, claim 7 or claim 8 wherein the RMS voltage of said alternating current signal is in the range 20 to 60 volts.

11. A method as claimed in any one of claims 1 to 10 wherein said pulse is of duration 1 to 10 milliseconds.

12. A method as claimed in any preceding claim wherein, after application of said pulse, a lower potential is applied to the device, sufficient to maintain the change of state.

13. A method as claimed in claim 12 wherein said lower potential is a DC voltage.

14. A method as claimed in claim 12 wherein said lower potential voltage is in the form of a pulsating DC voltage.

15. A method as claimed in claim 12 wherein said lower potential is an alternating current voltage.

16. A method as claimed in claim 15 wherein said alternating current voltage has a low frequency.

17. A method as claimed in claim 16 wherein said low freqency is in the range 25 to 120 Hz.

18. Means for applying electrical potential to a liquid crystal device for altering the state of the device, to vary the optical density of the device, arranged whereby on said applying of electric potential, the electric potential applied is generated as a relatively high magnitude pulse of short duration.

19. Means as claimed in claim 18 wherein said pulse has a peak potential of 2 to 5 times the critical voltage of the device.

20. Means as claimed in claim 19 wherein said pulse is formed from a high frequency alternating current signal.

21. Means for applying electric potential as claimed in claim 19 wherein said pulse is provided as a DC voltage.

22. Means for applying electric potential as claimed in claim 19 wherein said pulse is formed as a pulsating DC voltage.

23. Means for applying electric potential as claimed in claim 21 wherein said pulse is an alternating current signal.

24. Means as claimed in claim 23 wherein said alternating current signal has a frequency in the range 5 to 40 Khz.

25. Means as claimed in claim 23 wherein said frequency is substantially 20 Khz.

26. Means as claimed in claim 21 or claim 22 wherein the peak potential of said pulse is in the range 20 to 60 volts.

27. Means as claimed in any one of claims 23, 24 and 25 wherein the RMS voltage of said alternating signal is in the range 20 to 60 volts.

28. Means as claimed in any one of claims 18 to 27 wherein said pulse is of duration 1 to 10 milliseconds.

29. Means as claimed in any one of claims 18 to 28 wherein, after application of said pulse, a lower level of potential is applied to the device, sufficient to maintain the change of state.

30. Means as claimed in claim 29 wherein said lower potential is a DC voltage.

31. Means as claimed in claim 29 wherein said lower potential is in the form of a pulsating DC voltage.

32. Means as claimed in claim 29 wherein said lower potential is an alternating current voltage.

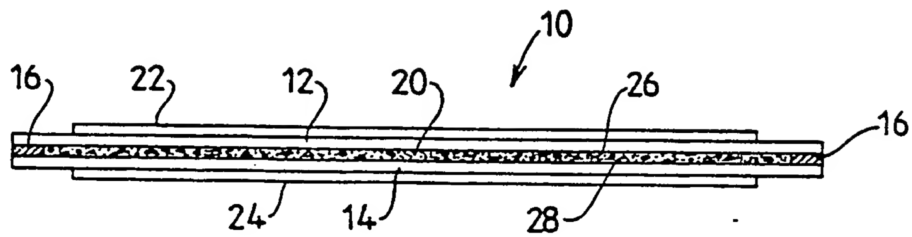
33. Means applying electric potential as claimed in claim 32 wherein said alternating current voltage has a low frequency.

34. Means applying electric potential as claimed in claim 32 wherein said low freqency is in the range 25 to 120 Hz.

35. Means applying electric potential as claimed in claim 18 comprising two voltage generators, one operable to apply a steady state voltage sufficient to maintain the liquid crystal display device in its changed state and a higher voltage generator operable to supply said pulse, together with control means operable on application of potential to the device to effect supply of potential from the higher voltage generator for the duration of said pulse and to then effect supply of potential from said one generator.

36. Means applying electric potential as claimed in claim 35 wherein said control means includes timing means effective to effect turning off of potential supply from the higher voltage generator to terminate said pulse.

FIG 1



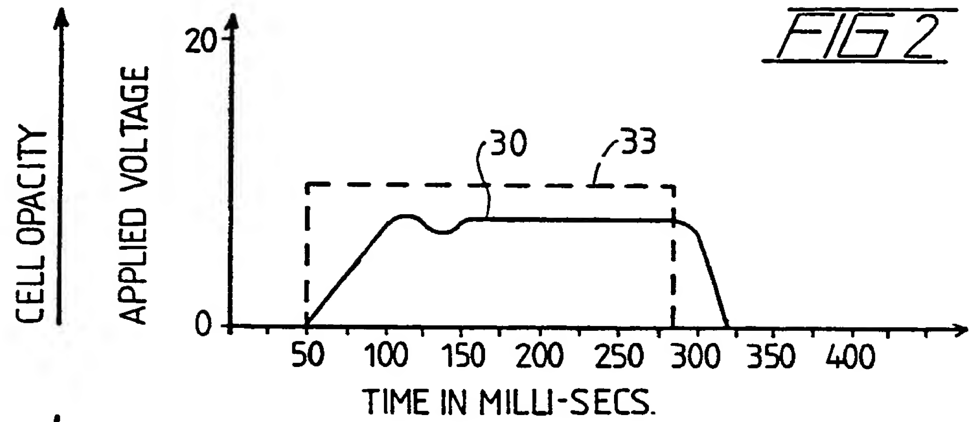


FIG 2

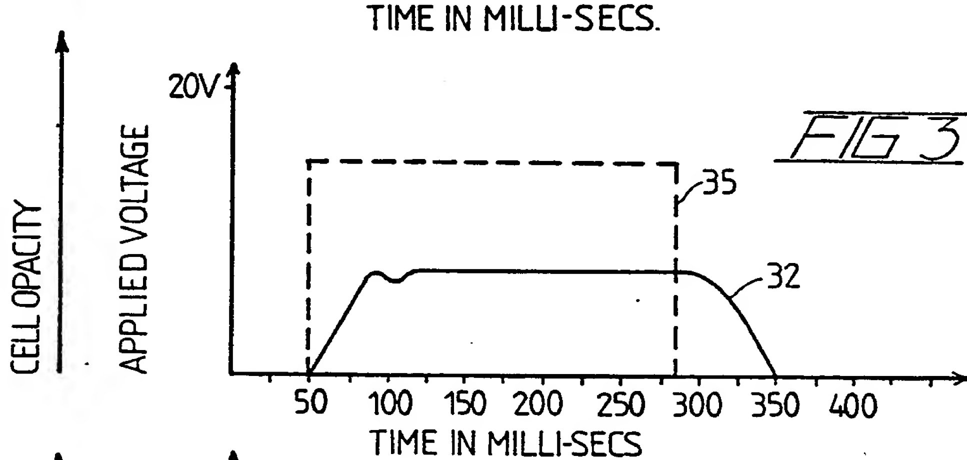


FIG 3

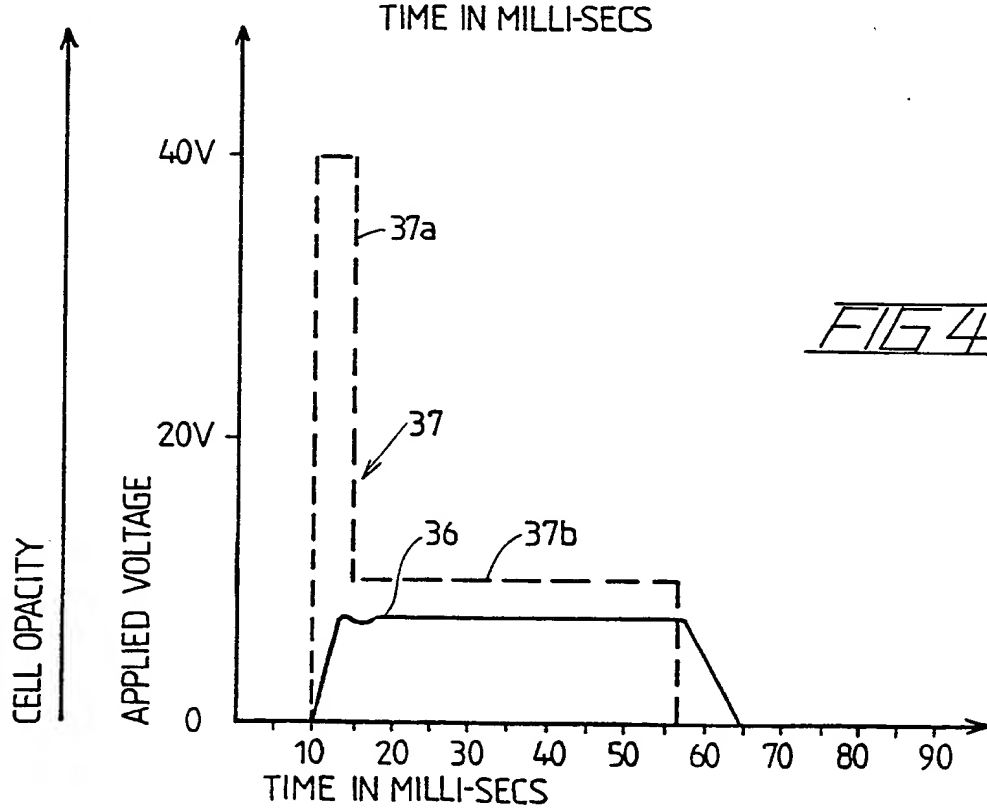


FIG 4

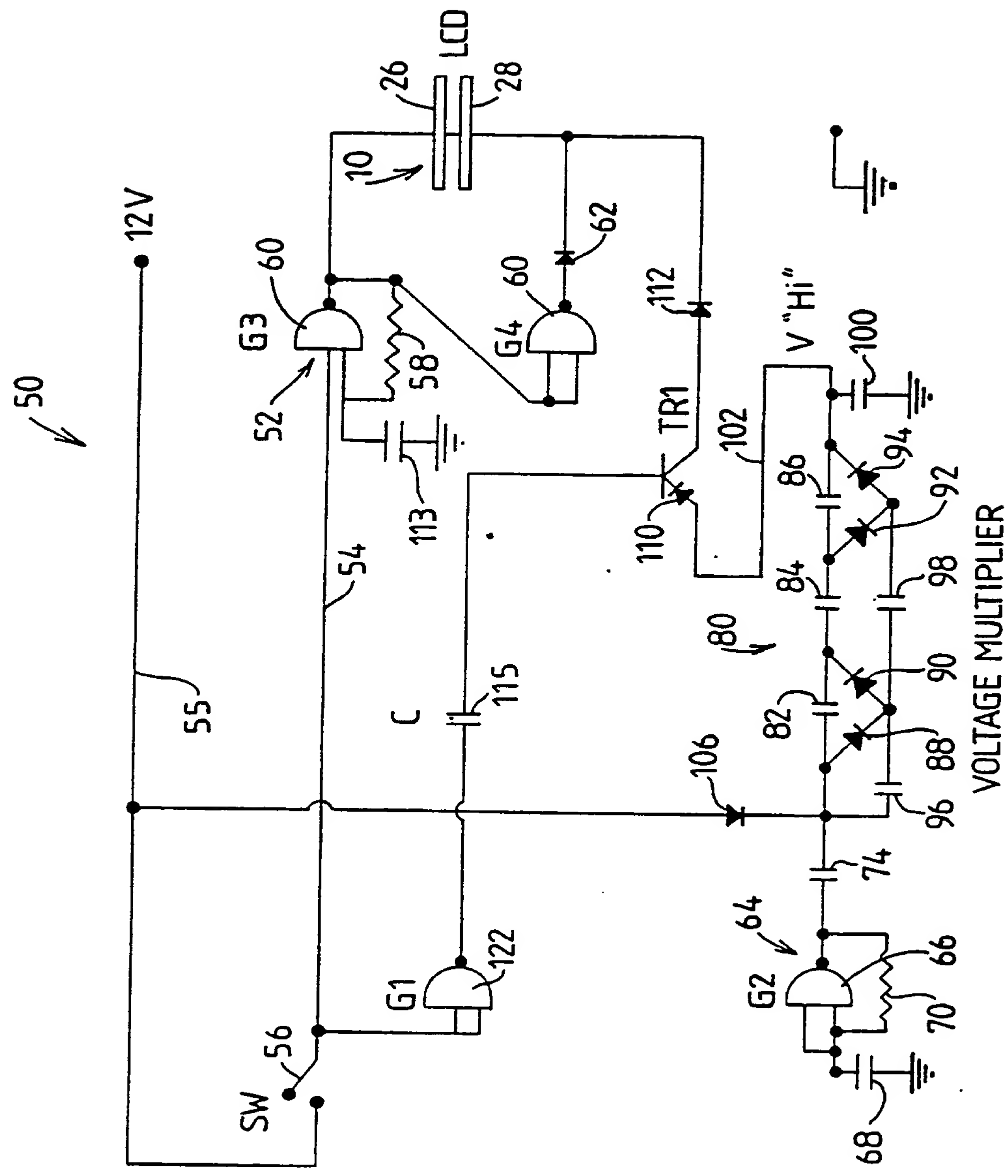

50
12V
55
54
SW
56
G1
122
C
115
G3
52
60
58
113
G4
60
62
10
26
LCD
28
112
TR1
110
102
V "Hi"
100
106
80
82
84
86
88
90
92
94
96
98
VOLTAGE MULTIPLIER
74
64
G2
66
70
68

FIG 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 86/00264

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.^{4} G02F 1/133

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
IPC	G02F 1/13, 1/133, 1/36, G09F 9/35

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched

AU : IPC as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	US,A, 3575491 (HELLMEIER) 20 April 1971 (20.04.71)	(1-36)
X	AU,A, 36078/84 (SEIKO INSTRUMENTS AND ELECTRONICS LTD) 13 June 1985 (13.06.85) See claim 6	(1-36)
X	US,A, 4161653 (BEDINI et al) 17 July 1979 (17.07.79)	1,2,4,5,9,18, 19,21,22,26
X	US,A, 4212010 (WALTER) 8 July 1980 (08.07.80) See column 2 lines 23-32	1,12,18,29
X	AU,A, 39068/85 (TOTH) 5 September 1985 (05.09.85) See pages 15 and 16	1,12,18,29
A	EP,A, 5417 (HORNELL) 14 November 1979 (14.11.79)	
A	EP,A, 92181 (HITACHI, LTD) 26 October 1983 (26.10.83)	
A,P	EP,A, 173246 (HITACHI, LTD) 5 March 1986 (05.03.86)	
A	US,A, 4279474 (BELGOROD) 21 July 1981 (21.07.81)	
A	US,A, 3655269 (HELLMEIER) 11 April 1972 (11.04.72)	
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A	GB,A, 1463979 (SECRETARY OF STATE FOR DEFENCE) 9 February 1977 (09.02.77)	

(Continued)

* Special categories of cited documents:

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
11 December 1986 (11.12.86)	(18.12.86) 18 DECEMBER 1986
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	M.E. DIXON

International Application No. PCT/AU 86/00264

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	FR,A, 2198167 (COMMISSARIAT A'L'ENERGIE ATOMIQUE) 29 March 1974 (29.03.74)	
A	JP,A2,55-111918 (DAINIPPON INSATU K.K.) 29 August 1980 (29.08.80) (JAPATIC English Language Abstract)	
A	AU,B, 39786/78 (525508) (SONY CORPORATION) 20 March 1980 (20.03.80)	

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers .... because they relate to subject matter not required to be searched by this Authority, namely:

2.☐ Claim numbers .... because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3.☐ Claim numbers .... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 86/00264

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members		
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US 4161653	AT 1367/78 FR 2381644	BE 864310 GB 1574674	ES 467271 SE 7802123
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